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SOME PRELIMINARY NOTES ON SOUTHWESTERN CORKY BARKS

by

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SOME PRELIMINARY NOTES ON SOUTHWESTERN CORKY BARKS

Three species of southwestern conifers have sufficient cork in their outer barks to be considered as possible emergency or temporary sources of commercial cork. The present international situation has greatly reduced imports of cork from cork oak (Quercus suber L.) of the Mediterranean region. Cork is a strategic material in National Defense, as well as an essential product for civilian use, and is on the priorities list set up by the Division of Priorities, Office of Production Management. Thus, the Government and cork manufacturing companies are interested in locating cork substitutes among barks of domestic species.

These circumstances have prompted, therefore, a series of preliminary studies and these notes on the corky barks, including the microscopic anatomy and formation of the cork, of the three most promising southwestern tree species. This report is to be followed by a more detailed technical article illustrated with drawings and photomicrographs. No studies on the commercial qualities of the cork have been made, this being left to the cork manufacturing companies which are best qualified to make the necessary tests.

The three species which appear to be the most likely possible sources of cork substitutes in the Southwest are corkbark fir (Abies arizonica Merriam), Douglas-fir (Pseudotsuga taxifolia (Poir.) Britton), and white fir (Abies concolor (Gord. and Glend.) Hoopes). Bark of all three species was collected in July 1941 from trees growing on San Francisco Mountain and vicinity on the Coconino National Forest near Flagstaff, Arizona.

CORKBARK FIR

Corkbark fir (*Abies arizonica* Merriam), as its common name suggests, has an unusual outer bark, which is a layer of pure, soft cork usually less than $\frac{1}{8}$ inch thick. This species was discovered on San Francisco Mountain, near Flagstaff, Arizona, by C. Hart Merriam in 1889 and was described by him as a new species in 1896. At present corkbark fir is usually considered as a variety of alpine fir under the scientific name *Abies lasiocarpa* var. *arizonica* (Merriam) Lemm. Because of its distinctive light gray or whitish, corky bark, it was soon introduced into horticulture as an ornamental. It is of limited range, being confined to poorly accessible subalpine forests at high altitudes in the mountains of Arizona, New Mexico, and southern Colorado.

Method of Formation of the Cork

The anatomical method of formation of the cork was studied through microscopic examination of bark from corkbark fir trees of various sizes growing at the type locality. The corky layer is the product of a single cork cambium (phellogen) which is formed during the first growing season of the young stem or twig and which remains active for the unusually long period of about 100 years or more. The persistence of this cork cambium, as in cork oak, is uncommon and of botanical interest as well as possible commercial importance.

The cork cambium arises in the outermost layer of cells of the cortex of the young stem, just inside the epidermis and outside a few rows of green collenchyma cells. By the end of the first growing season several rows of brown cork (phellem) cells have been formed between the epidermis and cork cambium. With the production of the corky layer, the stem changes from green to light brown or light gray in color. The epidermis is split lengthwise as the stem expands, and cracks appear along the stem in the second and third years. Within a few years the

epidermis sloughs off and the corky layer makes up the surface of the stem or twig.

A continuous layer of solid cork with few lenticels is formed outside the cork cambium. As the stem increases in diameter through activity of the cambium, the cork cambium keeps pace with the enlarged circumference and maintains the external cylinder of cork. However, the outer portion of the cork stretches and splits vertically as the stem expands. As a result, the thickness of the cork varies. It is greatest on the ridges which contain some of the oldest cork formed when the diameter was smaller and is least in the crevices formed by splitting apart of the outer portion.

The original cork cambium remains active until the stem is about 1 foot in diameter and more than 100 years old, but the rate of cork formation is very slow. At this stage the bark is relatively thin, only $\frac{1}{2}$ inch or less in thickness, of which less than one-half is cork. Presumably the cork cambium is killed by death of tissues inside as the bark becomes thicker. Some variation in the length of the period of activity of the cork cambium is to be expected, depending upon variation in rate of thickening of the bark among individual trees. After activity of the original cork cambium ceases, the outer corky layer of bark cannot increase in thickness.

The light gray corky bark is especially characteristic of the trunks and limbs up to 1 to $1\frac{1}{2}$ feet in diameter. The maximum thickness of this cork layer on the ridges is about 3/16 inch, or sometimes as much as $\frac{1}{4}$ to 5/16 inch. In the furrows the cork layer may be only 1/16 to 1/8 inch thick. Because the outer cork splits as the stem expands and because the surface gradually wears off, the average thickness of the cork layer does not continue to increase with increased diameter

of the stem. A stem 3 to 6 inches in diameter has cork of slightly greater average thickness than a stem 1 foot in diameter, though the volume of cork is greater in the larger stem.

On larger trunks the corky layer is cracked and split, and darker gray layers of harder bark formed later are visible. By the time a tree reaches large size with a trunk 2 to 3 feet or more in diameter, the fissured bark has become 1 to 2 inches thick. The much torn outer cork layer remains in separated patches on the most prominent ridges and slowly deteriorates and wears away.

Additional cork cambiums are formed deeper in the phloem after the first one becomes inactive. These are not continuous but form relatively thin lenticular layers of harder, reddish brown cork and are separated by larger masses of dark brown phloem parenchyma cells of the outer bark. The quantity of inferior cork produced by these later cork cambiums is low and probably totals less than one-fourth of the volume of the outer bark of a large trunk.

The corky outer bark, which is very resistant to decay and attacks by insects, persists on dead trunks and limbs and on logs long after the inner bark and part of the wood have decayed. The cork is not affected by bark beetles, which may destroy the inner bark.

Botanical Description of the Cork

Botanically, the outer layer of cork formed from the original cork cambium in corkbark fir is remarkably pure and homogeneous. A special feature is its softness and elasticity. Though the weathered surface is light gray, the cork in section has a light brown color, similar to that of cork from cork oak. Microscopically, the cork cells are similar to those of cork oak and, of course, are dead and filled with air. However, the cork cells in corkbark fir are somewhat larger

than those in cork oak, and this characteristic of larger cell size may account for the greater softness and elasticity of the cork of corkbark fir. The cells are not greatly elongated in any dimension but are rectangular in transverse and radial sections and rounded in tangential section. They are uniform and produced regularly in rows without other types of cells. A few lenticels are present as horizontally elongated deeper furrows of darker gray color. As lenticels and other openings are relatively few, there are unusually large thin areas of pure cork without openings of any kind. The cork of corkbark fir probably is as pure and uniform as that of any tree species in existence. Certainly no other tree species in the United States produces cork of the type found in cork oak in as pure layers.

The cork layer is marked by minute, faint, closely crowded lines, which presumably mark annual rings of growth, similar to the rings in wood and rings in cork from cork oak. Microscopically, the line is not formed by cells of different size and thickness of walls but is a single row of thickened cell walls.

The cork rings are more or less uniform in thickness but may become slighly smaller toward the inside next to the cork cambium. In fissures, where the outer cork stretches and breaks, the rings tend to be broader and additional, incomplete rings are common.

The maximum number of rings in a layer of cork at greatest thickness, usually less than $\frac{1}{4}$ inch, is 25 to 30 or more. However, in a fissure, where there are extra incomplete rings, double this number of rings may be counted. If these complete rings are annual rings, apparently the outer of these thin rings wear away relatively rapidly as the stem expands.

It is not known whether cork from corkbark fir will meet manufacturers' specifications in regard to quality. Because it is thin, the cork would not be suitable for use in stoppers. However, it perhaps would be satisfactory for various uses as ground cork and in thin sheets of pure cork. Possibly the thin strips could be glued together to form thicker cork layers.

Suggestions for Harvesting the Cork

Some preliminary suggestions on methods of harvesting the cork of corkbark fir are offered for use in the event that quality of the cork is found to be commercially satisfactory. In an emergency the high costs of harvesting this substitute cork may not be prohibitive. However, it seems likely that corkbark fir would be only an emergency or temporary source of cork rather than a permanent substitute for cork from cork oak.

First harvests with corkbark fir should be confined to salvage operations by getting the cork from dead trees and decaying logs. The cork can be stripped much more easily and more quickly from dead trees, in which the inner bark has partially decayed, than from living trees. A limited supply could be obtained from this source. On San Francisco Mountain, for example, cork could be removed from a number of trees which are dead and dying and infested with bark beetles. As corkbark fir is not being cut for lumber in the Southwest, it is not likely that the bark could be purchased from sawmills.

If the emergency should create sufficient additional demand for cork after the supply from dead trees and sawmill offal is consumed, possibly some removal of cork from living trees would be requested in spite of the high labor costs of stripping. Before stripping of cork on a large scale is attempted, experiments should be made to determine the best methods of stripping and the effects of stripping upon the trees.

The outer layer of cork can be removed with a knife by cutting and pulling off the cork which separates at the cork cambium. The thin cork layer is flexible and can be stripped off without difficulty. As the trees naturally have straight trunks with few limbs except small dead limbs, the bark peels off in uniform sheets of pure cork that can be packed in flat bales or in rolls.

It remains to be determined whether removal of the outer cork layer would injure or kill the tree. As the cork layer is entirely dead, a tree with the cork stripped off should not die, provided the living inner bark is not injured. It is possible, though, that removal of the protective layer of cork would subject the tree to attack by fungi or insects or would result in excessive exudation of resin.

The cork cambium probably would be destroyed in the stripping process. Whether stripping off the cork of a living tree would stimulate the tree to form a new continuous cork cambium and form another uniform outer layer of cork for possible future stripping, as in cork oak, should be learned through experiments.

If living trees are stripped, the operation should be limited to trunks not more than 1 to $1\frac{1}{2}$ feet in diameter. On larger trees the outer cork layer has become so torn apart into strips that it is inferior and could be removed only with difficulty, and the bark inside contains only a small proportion of cork.

The minimum size of trees to be stripped would have to be determined experimentally based upon effects of stripping on the trees and upon labor costs. Suitable cork of sufficient thickness occurs on stems as small as 3 inches or less in diameter and could be stripped from small limbs of large trees.

DOUGLAS-FIR

Douglas-fir (Pseudotsuga taxifolia (Poir.) Britton) has a thick outer bark which, though not of pure cork, contains nearly three-fourths or more cork. Having a very broad geographic distribution from Canada through western United States to northern Mexico, Douglas-fir forests are extensive and easily accessible. The botanist J. G. Lemmon, who visited San Francisco Mountain in 1884, noted that the bark of Douglas-fir here and elsewhere in Arizona and New Mexico was especially corky. In 1895 he gave this corky variation the descriptive scientific name Pseudotsuga taxifolia var. suberosa Lemm. While this variety is not distinguished at present, it is possible that the cork content of Douglas-fir bark varies somewhat in different parts of the range and that Douglas-fir bark from the Southwest would be preferred for cork.

In Douglas-fir the first cork cambium, which is formed the first growing season of the young twig, is active for a short period and produces only a few rows of cork cells. This cork cambium is located just inside the epidermis and outside the green collenchyma of the cortex. After the epidermis cracks in the second and third years, the thin corky layer remains at the surface for some years.

The corky bark begins to form before the stem reaches 6 inches in diameter. At this diameter the smooth gray bark begins to crack into long furrows exposing the lighter brown corky bark beneath. Cork cambiums are formed about 1/8 inch from the surface of the stem. These and other cork cambiums differentiated successively later and inward in the cortex and phloem produce thin to thick layers of cork of lenticular shape. These cork layers are only partly continuous and are separated by masses of soft, darker brown phloem cells.

As a trunk increases in diameter the bark becomes fissured with thick, light brown corky ridges. At a trunk diameter of 1 foot the corky ridges of outer bark are about 3/4 inch thick; at 2 feet in diameter, about $1\frac{1}{2}$ inches thick; at 3 feet in diameter, 2 inches thick; at 4 feet in diameter, 3 inches thick; and at 5 feet in diameter, 4 inches thick. Though some ridges have thick layers of almost pure cork, according to a rough estimate these thick ridges of outer bark contain nearly three-fourths or more cork.

The cork of Douglas-fir is similar botanically to that of cork-bark fir but differs in being lighter colored and not as soft. As the rings are slightly broador and the corky layers often much thicker, cork formation probably is more rapid and continues for a longer period in Douglas-fir.

If this cork meets manufacturers' requirements, bark of Douglas-fir should be a good source of ground cork. Possibly it would be suitable for low-grade stoppers also.

A large supply of Douglas-fir bark could be obtained easily and cheaply from sawmills over the large area occupied by forests of this species, though the volume available from logging operations in the Southwest would be small. The bark could be salvaged from slabs and sawmill waste at a much lower cost than that of harvesting the bark alone from living trees. The fissured, hard outer bark could not be removed in the field by stripping as easily as it could be chopped off with axes and other tools. As it is fairly resistant to decay, some bark could be salvaged from dead trees and logs. Perhaps the cork of Douglas-fir could be developed commercially as a by-product of lumbering operations.

WHITE FIR

White fir (<u>Abies concolor</u> (Gord. and Glend.) Hoopes) has outer bark similar to that of Douglas-fir but averaging only about one-half cork. This species is widely distributed from Oregon to Wyoming, south to California, New Mexico, and northern Mexico. Because of the lower portion of cork in the bark, white fir apparently would be less suitable for cork than the other two species.

Cork is formed in white fir in the same general manner as in Douglas-fir. The first cork cambium just inside the epidermis produces only a few rows of cork cells. The next cork cambiums arise about 1/8 inch from the surface when the stem is about 3 inches or more in diameter. These and other cork cambiums form thin, interrupted layers of hard cork separated by larger masses of phloem cells. Fissures in the bark appear when the stem reaches a diameter of 4 to 6 inches.

Thick corky ridges are formed at about the same rate as in Douglas-fir, as the trunk increases in diameter. In a trunk 3 feet in diameter these ridges are about 2 inches thick. This outer bark may average perhaps one-half or more cork. The cork of white fir is like that of Douglas-fir, botanically, but usually has a darker, reddish brown color. Bark could be obtained in the same manner, but the supply available from sawmills in the Southwest would be limited. However, it would seem that Douglas-fir bark, with its higher cork content, would have greater commercial possibilities.

SUMMARY

Three species of southwestern conifers have sufficient cork in their outer barks to be considered as possible emergency or temporary sources of commercial cork.

Corkbark fir has an unusual outer bark, which is a layer of pure, soft cork usually less than $\frac{1}{4}$ inch thick. A limited supply of this cork could be obtained by stripping dead trees and decaying logs. If necessary, cork could be stripped from living trees with trunks not more than 1 to $1\frac{1}{2}$ feet in diameter, but experiments should be made before large scale operations on living trees are attempted.

Douglas-fir has a thick outer bark which, though not of pure cork, contains nearly three-fourths or more cork. On large trunks the corky ridges become 2 to 4 inches thick. A large supply of bark of this species could be obtained easily and cheaply from sawmills.

White fir has outer bark similar to that of Douglas-fir but averaging only about one-half cork. Apparently this species would be less suitable for cork than the other two.